Routledge
Taylor & Francis Group

Journal of Environmental Policy & Planning

ISSN: 1523-908X (Print) 1522-7200 (Online) Journal homepage: https://www.tandfonline.com/loi/cjoe20

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To cite this article: Jonathan Pickering & Åsa Persson (2019): Democratising planetary boundaries: experts, social values and deliberative risk evaluation in Earth system governance, Journal of Environmental Policy & Planning, DOI: 10.1080/1523908X.2019.1661233

To link to this article: https://doi.org/10.1080/1523908X.2019.1661233

Published online: 09 Sep 2019.

JOURNAL OF ENVIRONMENTAL POLICY & PLANNING
https://doi.org/10.1080/1523908X.2019.1661233

Democratising planetary boundaries: experts, social values and deliberative risk evaluation in Earth system governance

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ABSTRACT

Recent debates about the concept of planetary boundaries recall longstanding concerns about whether ecological limits are compatible with ecological democracy. The planetary boundaries framework (originally set out in Rockström et al., 2009a, 2009b) defines values for key Earth-system processes such as climate change and biodiversity that aim to maintain a 'safe' distance from thresholds or levels that could endanger human wellbeing. Despite having a significant impact in policy debates, the framework has been criticised as implying an expert-driven approach to governing global environmental risks that lacks democratic legitimacy. Drawing on research on deliberative democracy and the role of science in democratic societies, we argue that planetary boundaries can be interpreted in ways that remain consistent with democratic decision-making. We show how an iterative, dialogical process to formulate planetary boundaries and negotiate 'planetary targets' could form the basis for a democratically legitimate division of labour among experts, citizens and policy-makers in evaluating and responding to Earth-system risks. Crucial to this division of evaluative labour is opening up space for deliberative contestation about the value judgments inherent in collective responses to Earth-system risks, while also safeguarding the ability of experts to issue warnings about what they consider to be unacceptable risks.

ARTICLE HISTORY
Received 28 November 2017
Accepted 30 May 2019

KEYWORDS
Planetary boundaries; ecological democracy; deliberative democracy; science-policy interface; Earth system governance; Anthropocene

1. Introduction

Is it possible to establish limits or boundaries that can contain humanity's impact on the earth while ensuring democratic legitimacy? This question speaks to two core challenges for research on ecological democracy: understanding the extent to which democratic processes and environmental protection are mutually reinforcing or in tension, and identifying ways of fostering synergies between them (see the Editorial for an overview of the literature). Longstanding debates over ecological limits have attracted renewed attention with the emergence of the concept of planetary boundaries. The term originates in research initiated by the Stockholm Resilience Centre and other institutions that identified 'control variables' or parameters for nine key Earth-system processes such as atmospheric carbon dioxide concentration, biodiversity, ozone depletion and freshwater use (Rockström et al., 2009b). For seven of those processes they proposed 'boundary values' for control variables, set at a 'safe' distance from a global threshold or tipping point – such as the melting of polar ice sheets, triggering multi-metre sea level rise – or more generally from a dangerous level (Rockström et al., 2009a, p. 32). Together, these boundaries define a 'safe operating space' for the Earth system in which 'humanity has the freedom to pursue long-term social and economic development' (Rockström et al., 2009a; for a revised version see Steffen et al., 2015).[1] The proponents of the framework warn that several of these boundaries had already

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been exceeded (see Steffen et al., 2015 for an updated version), and that humanity is at risk of transgressing further boundaries unless societies transform the ways in which they extract, modify and consume the planet's finite resources.

Since its original publication, the idea of planetary boundaries has received widespread attention from policy-makers and institutions (see, e.g. OECD, 2011; UNEP, 2012; United Nations Secretary-General's High-level Panel on Global Sustainability, 2012), and has had significant policy impact, at least at a rhetorical level. Nevertheless, the concept has also met with considerable resistance from some parts of the scientific and policy communities. While planetary boundaries featured in several drafts of UN decisions on sustainable development, ultimately the idea failed to be included in either the 2012 Rio + 20 outcome document or the 2030 Agenda that launched the Sustainable Development Goals in 2015 (SDGs; Schlosberg, 2016, p. 199).

An important critique of the framework is that it fails to account for the role of politics in setting collective goals.[2] One line of criticism is that the terminology of boundaries implies restricting opportunities for economic growth and development for developing countries (Linnér and Selin, 2013; see also Schlosberg, 2016, pp. 198–199). However, governments have been willing to set multilateral targets associated with several Earth system processes included in the planetary boundaries framework, such as limiting temperature rise or reversing stratospheric ozone depletion (Galaz et al., 2012). This suggests that, even though states remain intent on safeguarding their development aspirations, they are not altogether averse to setting coordinated constraints on how their economies operate in the interests of environmental protection.

Our focus in this article is on a related but distinct line of criticism: that the planetary boundaries framework is democratically problematic because it implies an expert-driven approach to global environmental governance that sidelines the participation of citizens and the diverse values they hold (Pielke, 2013; Stirling, 2015).[3] Those drawing on literature on ecological democracy, deliberative democracy and Science and Technology Studies (STS), we explore whether planetary boundaries could be defined and institutionalised in democratically legitimate ways. We argue that a democratic approach to planetary boundaries requires enhancing citizen participation in evaluating Earth-system risks. Nevertheless, expert warnings can serve an important function in a democratic conversation about those risks, provided that experts are transparent about the value judgments inherent in those warnings. The article aims thereby to advance understanding of how ecological democracy could be theorised and implemented at a global level, and to show how democratic principles and practices could inform the science-policy interface for Earth system governance.

We begin by elaborating upon democratic critiques of planetary boundaries and outlining an analytical framework that articulates the relationships between planetary boundaries, ecological democracy and deliberative democracy (Section 2). We then review four existing accounts of the role of experts in deliberation about values (Section 3) before presenting a revised account of the division of evaluative labour between experts, citizens and policy-makers that emphasises the need for iterative, dialogical deliberation over planetary boundaries and 'planetary targets' negotiated in policy settings (Section 4). Section 5 concludes with recommendations for further research.

2. Planetary boundaries, ecological democracy and the science-policy interface

2.1. Democratic critiques of planetary boundaries

Leach (2013) sparked a robust debate by arguing that the idea of the Anthropocene,[4] 'with its associated concepts of planetary boundaries […] is co-constructed with ideas of scientific authority and incontrovertible evidence; with the closing down of uncertainty or at least its reduction into clear, manageable risks and consensual messages' (see also Pielke, 2013 and Stirling 2015 for similar criticisms). Critics have fixed upon claims that planetary boundaries are 'non-negotiable' limits (Steffen, Rockström, and Costanza, 2011), or 'immutable facts emerging from the bio-geophysics of planet earth' that are 'immune to political pressure' (Chapron et al., 2017).

This critique – which we refer to as the 'technocracy critique' – speaks to broader debates in the fields of STS (Jasanoff, 2004; Lövbrand et al., 2011), democratic theory (Fischer, 2009) and philosophy of science (Kitcher, 2011) about how experts, policy-makers and citizens should interact to address collective problems. While

technocratic critiques are evident in earlier debates about ecological limits to growth (Eastin et al., 2011), planetary boundaries give rise to distinctive concerns due to a perception that they combine technocratic control with centralisation of power at a global level. Debates about planetary boundaries raise questions about who should have a say in what counts as a 'safe' or 'dangerous' operating space for humanity, and whether it is possible or even desirable to arrive at singular conclusions about these questions, given that exposure to danger and risk perceptions may vary widely across communities for any specified boundary value (Shaw, 2013).

Despite efforts to articulate how planetary boundaries can be compatible with principles of equity and justice (see, e.g. Raworth, 2017), there is little systematic analysis of whether planetary boundaries could be defined and institutionalised in a way that is democratically legitimate. Leach et al. (2013) suggest that three D's – direction, diversity and distribution – should be considered when formulating societal pathways for staying within planetary boundaries at the same time as satisfying minimum requirements of social justice. While the authors recognise that debates about societal pathways 'will need to be as open and inclusive as possible' and enable the voices of marginalised groups to be heard (p. 88), conspicuously missing is a fourth D: democracy.

2.2. Planetary boundaries and ecological limits as value-laden boundary objects

Planetary boundaries are commonly viewed as a new variation on discourses of ecological, environmental or biophysical limits (Meadowcroft, 2012). The planetary boundaries framework explicitly builds on previous articulations of global and sub-global limits, including 'limits to growth', 'critical loads', 'tolerable windows' and 'safe minimum standards' (Rockström et al., 2009a). Importantly, ecological limits are not purely scientific constructs but also involve normative decisions: 'the idea of a limit involves setting a maximum level of damage to a natural resource system that we are prepared to tolerate or accept' (Haines-Young et al., 2006, p. v). What is considered tolerable, acceptable or safe will depend on a range of normative or value judgments such as: the intrinsic or instrumental value that society places on the system compared to other social goals; how society values the wellbeing of the current generation compared to that of future generations; and social preferences about risk aversion (Renn, 2008). Limits need not be fixed in perpetuity but could vary over time along with changes in social values as well as ecological dynamics.

The definition of planetary boundaries quoted in the Introduction comprises two main components. First, planetary boundaries are defined by their *biophysical attributes*, since they focus on thresholds at the global level or sub-global thresholds that influence Earth system functioning. These attributes are ascertained through scientific inquiry. Rockström et al. (2009a, p. 31) argue that 'thresholds in key Earth System processes exist irrespective of peoples' preferences, values, or compromises based on political and socioeconomic feasibility'. This claim is valid to the extent that people's values do not affect the existence of the underlying biophysical dynamics that give rise to threshold effects. Nevertheless, even at the stage of understanding Earth system processes, values come into play when there are multiple possible control variables or thresholds for a given process. Thus the IPCC has recognised that 'it is […] not possible to define a single critical threshold [for dangerous climate change] without value judgments and without assumptions on how to aggregate current and future costs and benefits' (Collins et al., 2013, p. 1107).

Second, planetary boundaries are defined by their particular *normative orientation* or rationale, namely (i) the perception of an unacceptable risk or danger to humanity as a consequence of the Earth system 'tipping over' or shifting states, and correspondingly (ii) the need to ensure a 'safe' operating space worldwide. Even with processes that have one or more clear thresholds (e.g. conversion of coral reefs to algal-dominated systems as a result of ocean acidification), value judgements cannot be avoided when setting boundaries around those processes, as the question of how far a 'safe' distance from those points is involves irreducible normative choices about levels of acceptable risk (Moellendorf, 2011). The role of normative judgments in setting boundary values is even more apparent for biophysical processes that lack clear tipping points or thresholds (e.g. global biodiversity loss: Brook et al., 2013). Indeed, several originators of the proposal recognise that 'the position of the boundary is a normative judgment, informed by science but largely based on human perceptions of risk' (Steffen, Rockström, & Costanza, 2011, p. 61).

The fact that ecological limits contain an irreducible normative component means that defining planetary boundaries is a task that cannot be resolved by scientific expertise alone (unlike, say, identifying the temperature at which an ice sheet will melt). Thus, planetary boundaries – along with ecological limits – are best understood not as a purely scientific concept but rather as a 'boundary object', that is, 'a set of arrangements that allow different actors to cooperate on a basic common understanding while keeping the diversity of their views' (Biermann, 2012, p. 6; Morseletto et al., 2017; see also Bowker & Star, 1999).

2.3. Ecological democracy, deliberative democracy and the division of evaluative labour

Theories of ecological democracy provide a helpful starting point for thinking about how value judgments should enter into environmental decision-making processes, and whose values should count in these processes. For Eckersley (2004, p. 243), ecological democracy requires that 'all those potentially affected by ecological risks ought to have some meaningful opportunity to participate, or be represented, in the determination of policies or decisions that may generate risks'. While theories of ecological democracy place a strong emphasis on procedural criteria (such as citizen participation) as sources of democratic legitimacy, they also seek to advance substantive values, often understood as pro-environmental or 'green' outcomes. As outlined in the Editorial, the procedural and substantive dimensions of ecological democracy may sometimes be mutually reinforcing and at other times in tension.

Theories of ecological democracy commonly recognise that some forms of ecological limits are necessary preconditions for the exercise of democracy itself (Baber and Bartlett, 2005, p. 122). Thus, the core of the challenge is not whether ecological limits are compatible with ecological democracy in principle; it is whether democratic processes can deal with situations where people hold conflicting views on the substantive question of how stringent those limits should be. It is on these questions that theories of deliberative democracy can provide valuable guidance.

For theorists of deliberative democracy, democratic legitimacy requires that those who are affected by a decision have the opportunity to participate, or be represented in, deliberation that substantially influences the decision (Dryzek, 2010, p. 3).[5] Deliberative democracy is one of the most prominent theoretical perspectives for approaching ecological democracy: it argues that deliberation can secure procedural values while also increasing the value that participants place on shared substantive interests such as environmental protection (Smith, 2003; Dryzek, 2013). Deliberative democracy has opened up fertile ground for conceptualising global democracy in terms other than those based on electoral models, which are widespread at the domestic level but can less readily be scaled up to the global level (Baber & Bartlett, 2015; Editorial). In addition, a deliberative conception of legitimacy can clarify how individual citizens and organised civil society (for simplicity both are referred to together as 'civil society', while noting their differences), policy-makers (whether elected representatives or bureaucrats) and experts should relate to one another in a democratic polity under conditions of epistemic uncertainty and divergent values, and thus to construct an appropriate 'division of labour' among them (Mansbridge et al., 2012, p. 13; Klinke and Renn, 2014).

Establishing a democratically legitimate division of labour between experts, policy-makers and civil society will involve (among other things) building relationships of oversight and accountability while ensuring that experts have sufficient independence to minimise risks of ideologically motivated interference (Kitcher, 2011). However, our main concern here is with the division of 'evaluative' labour, i.e. the evaluation of evidence with a view to forming governance responses, as distinct from other kinds of labour such as the production or dissemination of new knowledge or the design of policy instruments. In the present context, the focus of evaluative labour is on the assessment of environmental (and specifically Earth system) risks and how to respond to them.

As with related research in Science and Technology Studies and the philosophy of science (e.g. Durant, 2011; Pielke, 2007; Kitcher, 2011), deliberative accounts generally view the science-policy interface not as a linear process whereby experts transmit scientific findings to policy-makers but rather as an iterative, dialogical process of engagement between policy-makers and experts (Edenhofer and Kowarsch 2015; Berg and Lindskog, 2018). The high regard that deliberative theories have for dialogue based on reasoning and reciprocal

justification of claims means that expert knowledge has an important role to play in informing democratic decision-making (Christiano, 2012; Fischer, 2009). Equally, citizens have a vital role not only in providing local and other forms of knowledge that may not be held by experts, but also in ensuring that decisions are responsive to their own values and preferences (Brown, 2016, p. 493; Mansbridge, et al., 2012, pp. 14–15).

Importantly, this does not mean that all the evaluative labour should be performed by civil society and policy-makers alone. Values play an important role in scientific practice by: influencing which lines of inquiry to pursue; informing standards for evaluating the quality of scientific work; and identifying societal implications of scientific findings (Edenhofer and Kowarsch, 2015; Kitcher, 2011). Moreover, as we outline in Section 3, expert advice to policy-makers may – subject to certain provisos – legitimately draw on experts' own normative values as well as on evidence about social values. Nuanced accounts of deliberative democracy stress that citizens' values may be transformed through interaction with experts as well as fellow citizens (Baber and Bartlett, 2005; Dryzek, 2010), and the same holds for experts' values. However, there remains a need for greater precision about how this interaction should function. We turn to this issue next.

3. Accounts of the roles of experts and policy-makers in deliberating over values

In this section, we compare four accounts of the division of evaluative labour between experts, policy-makers and civil society and show why each needs to be modified or supplemented to arrive at an account of planetary boundaries that satisfies principles of democratic legitimacy.

3.1. Referees and players

We begin with a metaphor adopted by some of the proponents of the planetary boundaries framework:

> [u]ltimately, there will need to be an institution (or institutions) operating, with authority, above the level of individual countries to ensure that the planetary boundaries are respected. In effect, such an institution, acting on behalf of humanity as a whole, would be the ultimate arbiter of the myriad trade-offs that need to be managed as nations and groups of people jockey for economic and social advantage. It would, in essence, become the global referee on the planetary playing field. (Steffen, Rockström, and Costanza, 2011)

While the playing field metaphor does not explicitly ascribe a role to experts, there is a clear implication that expert knowledge about boundaries is crucial in setting the 'rules of the game', and that experts would have an active role in any refereeing institution. Accordingly, critics such as Pielke (2013) have cited the metaphor to support their view that the framework implies an attempted 'power grab' whereby experts seek to institutionalise and enforce the boundaries through 'top-down', centralised global governance.

The account of Steffen et al. is compatible with the idea that societies (and the international community collectively) remain free to choose whether they want to appoint a referee at all, and if so on what terms – such an arrangement would not simply be imposed from above – but the metaphor is ultimately too constraining as it sheds little light on how experts and societies might interact in deciding the rules of the game.

A related concern about some accounts of planetary boundaries is the implicit assumption that expert authority over boundary-setting is permissible because it still leaves societies free to choose different pathways for sustainable development (see, e.g. Rockström et al., 2009a, p. 5). While there are indeed many possible development options that could be chosen within the 'safe operating space', this assumption tends to downplay the political and distributive dimensions of boundary-setting. Value conflicts in global environmental governance are often starkest in issues related to burden-sharing, namely how countries should distribute the collective effort of achieving a given ecological limit or target (see, e.g. Holz et al., 2018). But value judgments about distributional fairness, justice and inequality also feature in debates over how stringent the global limits themselves should be, not least because a higher or lower limit may affect some regions more than others. For example, a shift from 1.5°C to 2°C of global temperature rise (i.e. from the more stringent to the less stringent of the targets contained in the Paris Agreement) is likely to have severer effects on low-income countries than on wealthier countries (King and Harrington, 2018). Accordingly, a more nuanced division of labour is needed.

3.2. Mapmakers and navigators

A more fruitful account than the distinction between referees and players is offered by Edenhofer and Kowarsch (2015). They portray experts as 'mapmakers' who chart a range of possible societal pathways or scenarios based on different values, technological choices and policy instruments. Societies are then viewed as 'navigators' among the different pathways. Edenhofer and Kowarsch acknowledge that the exercise of mapmaking is not value-free, especially because value judgments are required to determine which policy options should be left off the map (e.g. if they are undesirable or unfeasible). But a key element of their account is that mapmaking involves outlining a variety of options informed by multiple value orientations, rather than prescribing a single policy option based on only one set of values. Applying this account to the planetary boundaries framework, scientists would map the risks associated with different boundary values, then leave it to society more broadly to chart its own course by deciding which of those alternative boundary values it wishes to adopt (e.g. which goal would be chosen for avoiding dangerous temperature rise).

In some respects the planetary boundaries framework represents a more 'hands-off', policy-neutral approach to mapmaking than that adopted by global knowledge assessment bodies such as the Intergovernmental Panel on Climate Change (IPCC) in dealing with individual boundaries, in that the framework does not specify which policy options for staying within the boundaries should be left on or off the map but leaves these choices to wider society. Nevertheless, by recommending specific boundary values, the planetary boundaries framework goes somewhat further in other respects than the map-making role outlined earlier. Specifically, planetary boundaries are based on value judgments made by the framework's proponents about what they consider to be an *unacceptable* level of risk (although, as outlined in Section 3.4, those judgments were based on a transparent evaluative benchmark). This highlights the need to consider whether a more expansive role for experts beyond mapmaking could be justified.

3.3. Honest brokers and issue advocates

On policy issues where values are contested, Pielke (2007, p. 142) emphasises the importance of experts – particularly those working through independent assessment bodies – as 'honest brokers of policy alternatives', a role that bears a strong resemblance to that of the 'mapmaker'. Nevertheless, he argues that scientists may legitimately advance specific policy recommendations based on their expertise, thus acting as 'issue advocates', as long as they are transparent about the values underpinning their recommendations (p. 7). Pielke bases this view on the observation that, in addition to their professional role, experts are also citizens with their own personal values (p. 32, 147). Recognising these values does not confer upon experts a unique kind of moral authority or insight that citizens lack. Nevertheless, experts' risk warnings may make a distinctive contribution to public debate because (i) experts' normative judgments may be less tainted by partisanship or self-interest than other participants in debate (e.g. national governments and businesses); and (ii) even if citizens likewise have a capacity for impartial reasoning, the cogency of risk warnings depends not only on the persuasiveness of one's normative convictions but also on an ability to interpret empirical evidence about the risks in question that may be less accessible to lay citizens.

Pielke's account of issue advocacy nevertheless remains limited, because he appears to envisage situations where experts align themselves with a political cause and he treats experts' values as personal and relatively static, whereas there may be other ways in which experts can integrate social value judgments with scientific knowledge and revise those judgments through deliberation, as we outline in subsequent sections.

3.4. Experts as risk advisers

A risk governance perspective can yield further insights on an appropriate division of evaluative labour. Klinke and Renn (2014) emphasise the importance of expert involvement in risk estimation, which includes empirical questions such as assessing the probability that a risk will eventuate and its likely consequences. Even at this stage, value judgments are inescapable on matters such as which categories of risk should be assessed, what constitutes a non-trivial risk worthy of estimation, and how the severity of consequences should be assessed

(Moellendorf, 2011; see also Renn 2008). Accordingly, Klinke and Renn (2014, p. 452) argue that risk estimation needs to be an interdisciplinary process informed by social scientific evidence on public risk perceptions. Nonetheless, they see the normative evaluation of risks as the province of stakeholders and citizens, and in this sense their account still resembles the mapmakers-and-navigators distinction outlined above.

The account we present here brings a risk governance perspective together with the preceding accounts to argue that it is legitimate for experts to issue warnings about unacceptable risks (rather than just mapping a range of options), subject to the proviso that they are transparent about the criteria they invoke to guide their warnings. In this way, experts could function not only as descriptive mapmakers but also as risk advisers or (to extend the cartographic analogy) 'warning sign-posters', in the sense that they may place warning signs at what they perceive to be a safe distance from hazardous areas on the map. Raworth (2017, p. 49) invokes such an image when she describes the process of defining planetary boundaries as 'equivalent to placing warning signs upstream of a river's treacherous but hidden waterfalls'.

Placing warning signs on the map of policy options could still be viewed as a kind of mapmaking, but it involves more than describing the features of the landscape: a warning sign carries with it a prescription as well (i.e. do not go over the waterfall/cross the planetary boundary). Whereas the mapmaker might set out the risks associated with different levels of temperature rise, the scientist as risk adviser might recommend that a particular level of temperature rise be avoided, based on their empirical knowledge of Earth system processes and their value judgments about unacceptable levels of risk. These prescriptions are non-binding: while they constitute one interpretation of what level of risk should be considered unacceptable, society may, in fact, be willing to accept a different level of risk. In other words, the navigators remain free to ignore the warning and choose a different path.

Ensuring transparency in the placement of warning signs is crucial as a safeguard against what Pielke (2007) calls 'stealth issue advocacy' (where experts voice political opinions under the guise of presenting purely scientific findings), and also as a basis for further deliberation among experts, policy-makers and civil society. The original version of the planetary boundaries proposal took what the proponents called 'a conservative, risk-averse approach to quantifying planetary boundaries' and stipulated that, to remain within planetary boundaries, the Earth system processes included should remain within or return to conditions that prevailed in the Holocene epoch, since those are the only conditions known to have accommodated large-scale human development (Rockström et al., 2009b, p. 473; see also Steffen, Persson et al. 2011, p. 753). While the Holocene baseline remains open to contestation (for a critique see Dryzek, 2016), it helps to provide a transparent basis for further debate.

4. Remodelling the division of evaluative labour on planetary boundaries

Employing the account we have just outlined, we can now develop a more precise and nuanced model of how a democratically legitimate division of labour on setting planetary boundaries could unfold through policy processes and deliberative interactions between experts, policy-makers and civil society.

4.1. Planetary boundaries and planetary targets

Even allowing that scientists may act as risk advisers by proposing planetary boundaries, what are we to make of the fact that international negotiations have already produced globally agreed 'warning signs' to help manage risks to the Earth system, such as the 1.5°C or 2°C temperature targets in the Paris Agreement on climate change? A simplistic account of this process might run as follows: experts set planetary boundaries; policy-makers set targets that either follow or ignore advice from experts; and policy-makers and experts deliberate over pathways for staying within those boundaries (see the 'linear model' in Figure 1). The preceding discussion has shown that this model is untenable as it involves too strict a separation between expert boundary-setting processes and social values.

An alternative approach would be to view planetary boundaries as a single boundary object, with experts, policy-makers and civil society each setting out their own visions of planetary boundaries, either jointly or in

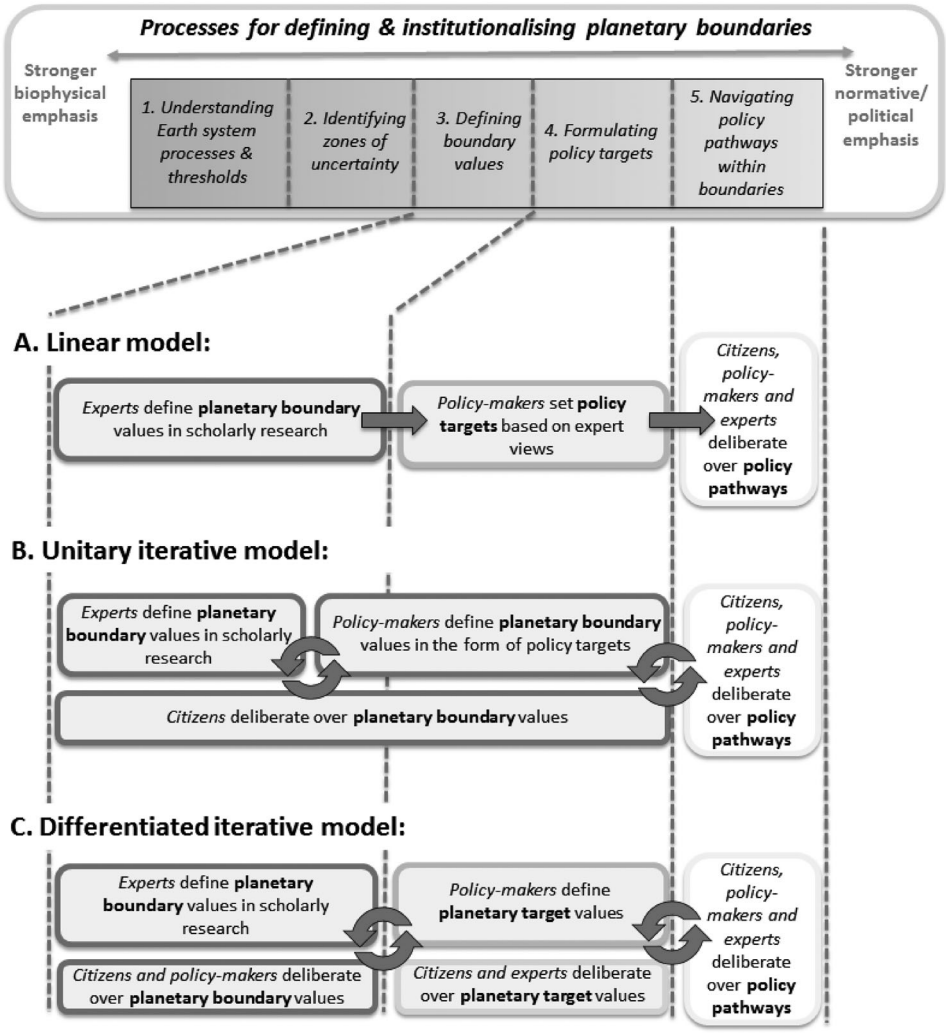

Figure 1. Models for defining and institutionalising planetary boundaries.

Straight arrows represent linear flows of communication, while circular arrows represent iterative dialogue. Shading of cells in models A-C shows planetary boundaries (dark grey), planetary/policy targets (medium grey) and policy pathways (light grey).The models are differentiated mainly at steps 3 and 4. We assume that steps 1 and 2 are scientific tasks undertaken primarily by experts.
Source: the authors.

parallel (see the 'unitary iterative model' in Figure 1). However, a unitary model that focuses on co-producing a single kind of object could conflate distinct forms of deliberative practice. For example, in contrast to the process of formulating the original planetary boundaries proposal, the process of negotiating the Paris Agreement's temperature targets was far more clearly shaped by broader political considerations, including what developed and developing countries could accept as a reasonable balance between environmental and economic objectives, and the need to craft a target that could be readily understood by the public and motivate further action. Society's decisions about how to respond to Earth system risks involve weighing a broader range of normative choices – including trade-offs with efforts to limit other kinds of societal risks (e.g. armed conflict) or to pursue other kinds of public goods (e.g. basic education) given limited resources – and it would be difficult for even the most sophisticated account of planetary boundaries to take all these considerations into account.

To develop a more nuanced division of labour we draw insights from Bäckstrand's (2017) account of critical loads for air pollution. Bäckstrand distinguishes between the task of setting *critical loads* – which remains primarily a task for experts in dialogue with policy-makers and citizens – and that of setting *target loads* – which represent the levels of air pollution that policy-makers view as acceptable and institutionalise in treaties and other policy instruments (Bäckstrand, 2017, p. 132). Target loads may correspond with critical loads but may also be more or less stringent. What makes the process of defining target loads distinctive is that considerations of political, technological and economic feasibility come into play more directly (Bäckstrand, 2017, p. 132).

The distinction between critical loads and target loads can inform our understanding of planetary boundaries by distinguishing between *planetary boundaries* as such – which are generated primarily through a process of scientific inquiry informed by societal judgements about risk – and *planetary targets* produced through political negotiations but informed by scientific efforts to identify planetary boundaries.[6] Planetary targets could take multiple forms, including international treaties (such as the Paris Agreement), multilateral declarations (such as the Sustainable Development Goals), commitments agreed by smaller 'clubs' of states, or proposals advanced by civil society organisations (as with the atmospheric carbon dioxide concentration target of 350 parts per million advocated by 350.org). This distinction is shown as the 'differentiated iterative model' in Figure 1. All three groups (policy-makers, experts and citizens) retain important roles under both models, but the planetary targets model gives a clearer articulation of the objects towards which the evaluative labour of each group is directed.

Distinguishing planetary boundaries and targets may help to relieve pressure on scientists to second-guess what kinds of boundary values might be viewed as politically acceptable in multilateral negotiations and may reduce the likelihood of political interference in boundary-setting processes. Moreover, the distinction can aid analytical clarity by making it possible to compare negotiated planetary targets with evolving understandings of planetary boundaries. In this way, planetary boundaries can serve as benchmarks for evaluating planetary targets, thus functioning in a manner similar to 'equity reference frameworks' that can facilitate deliberation about the fairness of national contributions to climate change mitigation (Holz et al., 2018).

4.2. Iterative deliberation about boundaries and targets

The final step in our revised account is to show how efforts to develop planetary boundaries and planetary targets need to be linked through iterative processes of deliberation. Differentiating planetary boundaries and planetary targets does not imply recreating a rigid demarcation between science and politics, or continuing to cordon off planetary boundaries as 'non-negotiable'. As the shading in Figure 1 shows, both tasks are situated on a spectrum that involves varying mixtures of knowledge about biophysical processes on the one hand and normative or political judgements on the other. Accordingly, both tasks require iterative dialogue between experts, policy-makers and civil society in two areas.

First, democratic legitimacy requires engagement between experts, civil society and policy-makers over planetary boundary values. This could occur either through formally organised deliberative processes in which experts, policy-makers and citizens exchange views face-to-face or through informal 'extended peer communities' (Funtowicz and Ravetz 1993) where scientific work on planetary boundaries is scrutinised in broader scholarly and public debate. Deliberative engagement can help to produce boundary values that are robust to societal perceptions about risks to the Earth system, both by testing experts' normative assumptions about unacceptable risks with a more diverse group, as well as by enabling citizens' and policy-makers' views to be better informed by empirical evidence about Earth system risks (Lo, 2013). Collaborative approaches are necessary where individual Earth system scientists lack the expertise or resources to conduct public opinion surveys or participatory exercises themselves (Kowarsch et al., 2016). Evidence from other experts (including economists and ethicists) may also inform scientists' judgments about risk (Kowarsch and Edenhofer, 2016) and open up space for fruitful interdisciplinary contestation.

Second, in contrast to the linear model, which assumes that planetary boundaries are set (by experts) first and decisions about policy pathways come later, under the differentiated iterative model decisions about

planetary boundaries, planetary targets and policy pathways are viewed as inter-related. As Edenhofer and Kowarsch (2015, p. 303) point out, societal ends and the means to achieve them are interdependent, and societal ends may need to be revised if the means to achieve them prove impossible. Accounts of planetary boundaries that recognise the need to encompass multiple levels of governance have largely focused on downscaling planetary boundaries to national or local levels and taking questions of social values into account at that stage (see, e.g. Cole, Bailey, and New, 2014; Dearing et al., 2014). However, evidence about what should and can be done at the local level – such as strategies to reduce greenhouse gas emissions or conserve biodiversity – is crucial for informing decisions about the desirability and feasibility of planetary targets. Accordingly, there is a need not only for small-scale deliberative processes to clarify communities' priorities for managing local and global risks, but also for national and transnational deliberation that brings together citizens from different localities and countries to 'upscale' their preferences into international policy-making, and to identify and build areas of shared understanding over how to respond to global risks (Dryzek and Pickering 2019). Political debate about target values may also reveal changing societal perceptions of risk that could inform future assessments of boundary values.

5. Conclusion

In this article, we have argued that the idea of planetary boundaries is compatible with a democratically legitimate approach to governing risks to the Earth system, even though some arguments put forward by its proponents (e.g. the referees and players analogy and the 'non-negotiable' nature of the boundaries) convey a more technocratic view of relationships between experts and wider society. The division of evaluative labour we have set out helps to respond to the technocracy critique by showing how planetary boundaries can be informed by social values about unacceptable risks, and how planetary targets can be informed by scientific understanding of the Earth system. A dialogical process between experts, policy-makers and civil society over planetary boundaries and planetary targets can reduce the likelihood that expert assessments of risk will be fundamentally at odds with citizens' preferences, while also opening up the possibility that citizens' and experts' perceptions about risk may be transformed through deliberative processes.

Establishing the feasibility of democratising planetary boundaries is only an initial step; it does not guarantee that any future boundary-setting efforts will be democratically legitimate. Accordingly, further research could build on the framework outlined here to: (i) evaluate the legitimacy of processes enacted to date for defining individual boundaries and targets in areas such as climate change, ozone layer depletion and biodiversity loss; and (ii) identify institutional arrangements that could help to achieve a legitimate division of evaluative labour in defining planetary boundaries and targets.

The account we have given may help to inform broader debates about whether ecological limits and ecological democracy can be reconciled. In this regard, Purdy (2015, p. 268) provides an apt perspective on the relationship between these two ideas when he argues that the Anthropocene requires

> a democracy capable of self-restraint. But, ironically, democratic self-restraint can come only from democratic self-assertion: a political community must be able to act effectively and decisively on hard questions in order to commit to accepting certain limitations. The ultimate political challenge is to limit, together and legitimately, the scope of human appetites, so that we do not exhaust and undo the living world. Our demands must have their boundaries.

Planetary boundaries can, in our view provide limits of this kind and, in doing so can help to build the foundations for ecological democracy.

Notes

1. The Earth system refers to 'Earth's interacting physical, chemical, and biological processes. The system consists of the land, oceans, atmosphere and poles. It includes the planet's natural cycles – the carbon, water, nitrogen, phosphorus, sulphur and other cycles – and deep Earth processes' such as plate tectonics and volcanic activity (IGBP, 2017).
2. On critiques of the scientific basis for the planetary boundaries concept, which we do not discuss here in detail, see Brook et al. (2013); Lewis (2012).

3. In this article the term 'experts' refers not only to natural scientists but also to others recognised as having specialised knowledge in a particular area, including researchers in the social sciences and humanities, and practitioners with legal or administrative expertise. All of these types of expertise may be relevant to debates about planetary boundaries, but within the limited scope of the article, we focus primarily on the role of natural scientists, who have been the main proponents of the framework.
4. The Anthropocene refers to the idea that the planet has entered a new geological epoch due to humanity's pervasive influence over the Earth system (Dryzek and Pickering, 2019; Steffen et al., 2011).
5. Deliberation refers to 'debate and discussion aimed at producing reasonable, well-informed opinions in which participants are willing to revise preferences in light of discussion, new information, and claims made by fellow participants' (Chambers, 2003, p. 309).
6. One could also envisage a further category of broad *planetary goals* (goals being understood here as 'non-operational overarching objectives that usually require [quantified or numerical] targets in order to achieve them': Morseletto et al., 2017, p. 657). An example of a (de facto) planetary goal would be Sustainable Development Goal 13 ('Take urgent action to combat climate change and its impacts').

Acknowledgements

Earlier versions of this paper were presented at a workshop held at the University of Sydney on 'Ecological democracy: always greener on the other side?' (2017), at the Earth System Governance conference in Lund (2017), and at the conference on 'A crisis of expertise?' at the University of Melbourne (2018). We are grateful to participants in the presentations, as well as to Karin Bäckstrand, John Dryzek, James Meadowcroft and David Schlosberg, for helpful feedback. Two anonymous reviewers provided insightful comments which helped to improve the paper considerably.

Disclosure statement

No potential conflict of interest was reported by the authors.

Funding

This work was supported by the Australian Research Council's Laureate Fellowship funding scheme under Project number FL140100154 and the Swedish Research Council Formas (Formas) grant number 211-2012-1842.

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